

Herd of cows used in feeding experiments

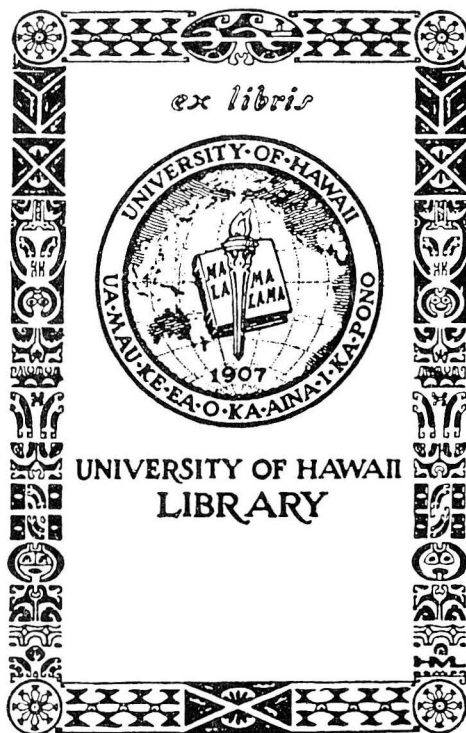
Protein Sources and Supplements for Dairy Cows in Hawaii

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Protein Sources and Supplements for Dairy Cows in Hawaii

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INTRODUCTION

In Hawaii, dairy cattle, land, and equipment are expensive and labor costs are high. Practically all milk is sold for direct consumption rather than for conversion into dairy products and, though the cost per unit quantity of milk produced is high, returns are also high. It would, therefore, be poor economy to limit milk production by withholding any feed that would contribute toward maximum returns. If an added pound of concentrate at a cost of three cents will produce an added pound of milk worth five cents or more, it is obviously good business to provide the added feed.

Hawaii produces none of the oil cake meals of high protein content necessary to supplement the pineapple bran and cane molasses usually fed to dairy cattle in the islands. These by-products of our two major industries are excellent sources of carbohydrates and are cheap and readily available, but cane molasses carries about 1 per cent digestible crude protein and pineapple bran somewhat less. Furthermore, Napier grass and Panicum grass, the roughages most commonly fed to dairy cows in Hawaii, are also low in protein. When large amounts of these locally produced, relatively low cost by-products are included in a ration, it is highly essential that they be supplemented with protein concentrates in order to insure high milk production.

For many years prior to the war, it had been the practice of some dairymen in Hawaii to feed materially more protein than is specified by the Morrison Standard¹ of requirements for lactating cows. During that period, the price difference between oil cake meals and high grade cereals was not great. For example, during the summer of 1932, barley sold for \$24 a ton, corn meal for \$33, and soybean oil meal for \$33 a ton. At these low prices, the addition of an excess of soybean oil meal to rations added little to the total cost.

In contrast to Hawaii practice, cereal grains such as barley, oats, and corn usually form a major part of dairy rations on the Mainland. Such feeds contain 7 to 9 per cent digestible crude protein, and a total digestible nutrient content of between 70 and 80 per cent, in contrast to pineapple bran and cane molasses in which the total digestible nutrients range from but 60 to 65 per cent. To compensate for this difference, the Hawaii dairyman adds concentrate in the form of oil cake meals to increase both the protein and the total nutrients of the ration. He may use one pound of concentrate for each two pounds of milk produced, whereas the rate in most sections of the Mainland is one pound of concentrate to three pounds of milk. With the higher rate of feeding, the protein percentage of the Hawaiian ration can be less than that of the Mainland ration since the greater quantity fed compensates for the lower protein content.

¹ F. B. Morrison, *Feeds and Feeding* (20th ed.; Ithaca: 1936), p. 1004.

In numerous feeding trials at the Hawaii Experiment Station it has been found that 12 per cent digestible protein in the ration with the heavy feeding practiced in Hawaii, meets the requirements of the Morrison Standard. On the Mainland, however, dairy concentrate rations often carry 15 to 18 per cent digestible crude protein; but less of such a ration is fed per unit quantity of milk produced. Dairymen in Hawaii who rely largely on imported feeds could adopt the Mainland practice of feeding smaller quantities of the higher protein rations.

Various experiments to determine the quantity of protein supplements needed, the relative value of imported supplements, and the possibility of replacing such supplements with locally produced concentrates and with such legumes as pigeon peas and koa haole, have been conducted at the Hawaii Experiment Station. Condensed results of these experiments form the basis of this bulletin and are presented in the sections which follow.

PRELIMINARY STUDIES OF PROTEIN CONTENT OF RATIONS

Observation Experiment I.

In a preliminary observation trial at the Hawaii Experiment Station, nine cows were fed a concentrate mixture containing 20.2 per cent digestible crude protein for periods of from two to eighteen months. The control concentrate ration contained only 10.5 per cent digestible crude protein. Both rations, including the roughages, supplied approximately equal amounts of total nutrients. However, the high protein mixture provided an excess of nearly 50 per cent protein above Morrison Standard requirements.

Milk yields of cows on control rations before and after the test period were compared with milk production during periods when the cows were on the high protein ration. No statistical analysis of the production records was made since it was considered that factors other than the protein content of the ration may have operated to influence milk production in a long-time experiment of this kind. In general, however, milk production was not definitely and consistently higher when the high protein ration was fed. There was some indication that cows on the high protein ration showed somewhat less of a decline in milk production during the lactation period.

Observation Experiment II.

In a fifteen-week, double reversal experiment with eight cows, a high protein ration containing 20.2 per cent estimated digestible crude protein and 71.8 per cent total digestible nutrients was compared with a low protein ration containing 10.8 per cent digestible crude protein and 70.8 per cent total digestible nutrients. Percentage composition of the two rations is shown in Table 1.

Table 1. Composition of low and high protein rations

Feed	Low protein ration	High protein ration
	<i>Per cent</i>	<i>Per cent</i>
Barley	30.5	24.8
Corn meal	20.3	0.0
Wheat bran	40.7	39.7
Soybean oil meal.....	0.0	33.1
Coconut oil meal.....	4.1	0.0
Linseed oil meal.....	2.0	0.0
Raw rock phosphate.....	1.2	1.2
Salt	1.2	1.2
Estimated Digestible Crude Protein.....	10.8	20.2
Estimated Total Digestible Nutrients.....	70.8	71.8
Cost per ton*	\$26.80	\$27.20

* In 1932 when this experiment was conducted.

Consumption of the high and low protein rations and amount and quality of milk produced during the experimental period, are summarized in Table 2. The 3.7 per cent increase in milk production of cows receiving excess protein from the high protein ration is not statistically significant.

Table 2. Feed consumption, live weights, milk production, and percentages of fat in milk of cows fed low and high protein content concentrates

Ration	Concen- trates consumed per cow per day*	Green roughage consumed per cow per day	Live weights	Milk production per cow per day	Butterfat content of milk	Daily milk production on a 4 per cent fat corrected basis†	Superiority in milk production on a 4 per cent fat corrected basis
	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Per cent</i>	<i>Pounds</i>	<i>Per cent</i>
Low protein.....	12.67	52.2	946	26.20	3.66	24.86	....
High protein.....	12.69	52.2	952	26.86	3.73	25.77	3.7‡

* Includes two pounds beet pulp.

† In this and in subsequent tables on milk production, the data on the 4 per cent fat corrected basis are calculated according to Gaines' formula— $(0.4 \times \text{pounds of milk}) + (15.0 \times \text{pounds fat}) = 4 \text{ per cent fat corrected milk}$.

‡ This superiority is not statistically significant. Significance in this and later trials determined according to methods outlined in A. E. Brandt, "Tests of Significance in Reversals or Switchback Trials," Iowa Agricultural Experiment Station Research Bulletin 234: 64-66. 1938.

That both rations supplied adequate amounts of digestible total nutrients is indicated in Table 3 by the comparison with requirements set by the Morrison Standard. It is also shown that the low protein ration supplied slightly more than the required amount of digestible crude protein.

Table 3. Nutrients required according to the Morrison Standard and supplied by the high and low protein experimental rations

Requirements and sources	Digestible crude proteins	Total digestible nutrients
	<i>Pounds</i>	<i>Pounds</i>
<i>Required for—</i>		
Maintenance of a 950 lb. cow.....	0.62	7.58
Production of 25 lbs. 4 per cent F. C. milk.....	1.22	8.10
	1.84	15.68
<i>Supplied by—</i>		
52.2 lbs. mixed green roughage	0.93	7.20
2.0 lbs. beet pulp	0.10	1.44
<i>Sub-total</i>	1.03	8.64
10.67 lbs. low protein concentrate	1.15	7.55
<i>Total</i>	2.18	16.19
10.69 lbs. high protein concentrate	2.16	7.68
<i>Total</i>	3.19	16.32

PROTEIN CONCENTRATE SUBSTITUTES FOR SOYBEAN OIL MEAL

Sesame Oil Meal.

Although soybean oil meal is the common protein supplement used in dairy cow rations in Hawaii, sesame oil cake has been used occasionally in the past and may again be available after the war. The value of these oil meals as ration components was compared in two double reversal, twelve-week trials. Six cows were used in each trial. Composition of the rations used is given in Table 4 which shows that the rations differed only in the oil meal used. Chopped Napier grass was included as roughage with both concentrate rations.

Table 4. Composition of sesame oil meal and soybean oil meal rations

Feed	Soybean oil meal ration	Sesame oil meal ration
	<i>Pounds</i>	<i>Pounds</i>
Soybean oil meal.....	200	0
Sesame oil meal.....	0	200
Rolled barley.....	300	300
Wheat bran.....	480	480
Bone meal.....	12	12
Salt	12	12
Estimated Digestible Crude Protein.....	15.44%	15.50%
Estimated Total Digestible Nutrients.....	73.12%	72.37%

Results of chemical analyses of the oil meals used in the two experiments are summarized in Table 5.

Table 5. Analyses of soybean and sesame oil meals*

Feed	Moisture	Crude protein	Fat	Crude fiber	N-free extract	Ash
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
<i>Soybean oil meal</i>						
Trial I.....	7.99	44.38	7.64	5.94	28.24	5.81
Trial II.....	12.32	40.87	8.78	4.95	28.03	5.05
<i>Sesame oil meal</i>						
Trial I.....	5.99	41.00	9.70	7.22	23.55	12.54
Trial II.....	6.86	38.07	13.36	6.17	21.53	14.01

* On air dry basis as fed.

Data in Table 6 on feed consumption and on amount and quality of milk produced during the trials, show that sesame oil meal as used in these experiments was an adequate substitute for soybean oil meal. In the second of the two trials, the sesame oil meal ration resulted in a statistically significant increase in milk production.

Table 6. Feed consumption, live weights, milk production, and percentages of fat in milk of cows fed soybean and sesame oil meal concentrate rations

Ration	Concentrates consumed per cow per day	Green Napier grass consumed per cow per day	Live weights	Milk production per cow per day	Butterfat content of milk	Daily milk production on a 4 per cent fat corrected basis	Superiority in milk production on a 4 per cent fat corrected basis
	Pounds	Pounds	Pounds	Pounds	Per cent	Pounds	Per cent
<i>Soybean oil meal</i>							
Trial I.....	13.3	53.8	974	23.3	4.08	23.58	.....
Trial II.....	14.2	49.2	1000	25.0	3.47	23.00	.....
<i>Sesame oil meal</i>							
Trial I.....	13.4	55.0	978	23.4	4.12	23.82	1.06*
Trial II.....	14.2	51.6	1027	25.9	3.49	23.91	3.95†

* Not statistically significant.

† Statistically significant.

Cottonseed Oil Meal.

Cottonseed oil meal, which is occasionally available in Hawaii, was compared with soybean oil meal in two twelve-week, double reversal experiments. Eight cows were used in each of the experiments and, as in the trials with sesame oil meal, chopped Napier grass was supplied as roughage. Feed components of the two rations used are listed in Table 7.

Table 7. Composition of cottonseed oil meal and soybean oil meal rations

Feed	Soybean oil meal ration	Cottonseed oil meal ration
	<i>Pounds</i>	<i>Pounds</i>
Pineapple bran.....	500	500
Cane molasses.....	500	500
Linseed oil meal.....	300	300
Soybean oil meal.....	600	0
Cottonseed oil meal.....	0	600
Coconut oil meal.....	60	60
Salt	20	20
Steamed bone meal.....	20	20
Estimated Digestible Crude Protein.....	16.35%	15.47%
Estimated Total Digestible Nutrients.....	68.65%	65.84%

Comparative chemical analyses of the oil meals used in the rations tested in this experiment are presented in Table 8.

Table 8. Analyses of soybean and cottonseed oil meals*

Feed	Moisture	Crude protein	Fat	Crude fiber	N-free extract	Ash
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
<i>Soybean oil meal</i>						
Trial I.....	11.81	42.03	6.18	5.32	28.44	6.22
Trial II.....	12.01	41.84	5.81	5.30	29.12	5.92
<i>Cottonseed oil meal</i>						
Trial I.....	10.04	41.60	7.73	10.11	23.79	6.73
Trial II.....	10.38	40.08	7.32	10.07	25.45	6.70

* On air dry basis as fed.

Table 9 summarizes results of the two trials of the cottonseed and soybean oil meal comparisons. Both test rations more than satisfied protein requirements and the slightly lower protein content of the cottonseed oil meal (shown in Table 8) was not a limiting factor. However, in Trial I of the comparison (Table 9), the Napier grass supplied was apparently too mature and the experimental cows did not consume enough to meet total nutrient requirements. This deficiency, combined with the lower total nutrient content of the cottonseed oil meal, increased the inadequacy of this ration.

Table 9. Feed consumption, live weights, milk production, and percentages of fat in milk of cows fed soybean and cottonseed oil meal concentrate rations

Ration	Concentrates consumed per cow per day	Green Napier grass consumed per cow per day	Live weights	Milk production per cow per day	Butterfat content of milk	Daily milk production on a 4 per cent fat corrected basis	Superiority in milk production on a 4 per cent fat corrected basis
	Pounds	Pounds	Pounds	Pounds	Per cent	Pounds	Per cent
<i>Soybean oil meal</i>							
Trial I.....	12.44	36.4	1069	24.61	3.84	24.02	3.71*
Trial II....	16.98	52.4	1144	33.37	3.57	31.20	0.78*
<i>Cottonseed oil meal</i>							
Trial I.....	12.44	36.0	1066	23.28	3.97	23.16	.....
Trial II....	17.01	53.5	1138	32.80	3.63	30.96	.....

* Not statistically significant.

Cane Molasses Yeast.

Dried yeast made from molasses is not at present available commercially but for a number of years it was made in an experimental plant at the Hawaiian Sugar Planters' Experiment Station, and at present a commercial plant making yeast for human consumption is in operation on one of the plantations. Whether locally produced yeast will later be available in quantities large enough to provide yeast supplement for dairy cow feeding will doubtlessly depend on the cost of making molasses yeast in comparison with the cost of importing protein supplements.

With future use in mind, it seemed desirable to secure data on the use of dried yeast as a substitute for imported oil cake meals. Molasses yeast was obtained from the Hawaiian Sugar Planters' experimental plant and three double reversal experiments were conducted at the Hawaii Experiment Station. Percentage composition of rations fed in these experiments is given in Table 10.

Table 10. Composition of dried yeast and control rations

	Experiment I		Experiment II		Experiment III*	
	Yeast	Control	Yeast	Control	Yeast	Control
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Cane molasses	25.0	25.0	25.0	25.0	25.0	25.0
Pineapple bran	38.0	38.0	32.0	35.5	38.0	38.0
Coconut oil meal	0.0	10.0	8.5	7.0	4.0	10.0
Soybean oil meal.....	0.0	25.0	0.0	27.5	4.5	25.0
Copra	0.0	0.0	5.0	3.0	1.5	0.0
Dried molasses yeast	35.0	0.0	27.5	0.0	25.0	0.0
Salt	1.0	1.0	1.0	1.0	1.0	1.0
Steamed bone meal	1.0	1.0	1.0	1.0	1.0	1.0
Estimated D. C. P. †	10.69	11.30	10.32	11.78	10.21	11.30
Estimated T. D. N. ‡	60.51	67.84	65.21	69.51	63.26	67.84
Estimated T. F. §	1.33	3.13	4.84	4.85	2.67	3.13

* Conducted by L. E. Harris, Junior Animal Husbandman. Resigned June, 1941.

† Digestible crude protein.

‡ Total digestible nutrients.

§ Total fat.

The values shown in Table 10 for estimated digestible crude protein and for total nutrients are based on standard analyses of the feeds used and on the results of application of known or assumed coefficients to these analyses.

In rations in which yeast was used, it was difficult to raise the total of digestive nutrients to the level of the control rations but in Experiments II and III, addition of copra partially remedied the deficiency and supplied fat as well. Chemical analysis of the yeast and control mixtures used in all three experiments is presented in Table 11.

Table 11. Chemical analysis of molasses yeast and of control and yeast mixtures

Feed or ration	Average percentage on air dry basis as fed						
	Number of analyses	Moisture	Protein	Fat	Fiber	N-free extract	Ash
Molasses yeast	5	8.95	38.80	1.91	6.13	30.19	14.01
<i>Experiment I</i>							
Control mixture	3	20.91	14.97	2.56	11.54	41.88	7.47
Yeast mixture	3	20.23	16.40	0.78	10.00	42.16	10.43
<i>Experiment II</i>							
Control mixture	3	18.86	13.59	3.21	10.46	44.63	9.27
Yeast mixture	3	17.80	14.04	3.70	8.58	44.48	11.40
<i>Experiment III</i>							
Control mixture	3	16.04	15.07	1.33	9.81	48.74	9.01
Yeast mixture	3	15.31	13.14	1.64	10.37	48.98	10.27

Seven cows were used in the first experiment and eight in the second in the twelve-week test of the value of molasses yeast as a protein supplement. In the third experiment, which was conducted by L. E. Harris, six cows were fed the test rations for fifteen weeks. Non-legumes, largely Napier grass, were supplied as roughage in all experiments. Assuming that nutrients in dried yeast are 75 per cent digestible (digestion coefficients not available), nutrient needs based on Morrison Standards were met in all experiments.

Based on 4 per cent fat corrected milk production (Table 12), dried molasses yeast was inferior to oil cake meals in the first two experiments and slightly superior, but not to a statistically significant extent, in the third experiment. However, average butterfat content of milk of cows fed the yeast ration was 3.82 per cent, and of cows on the control ration, 3.60 per cent. When fed the yeast ration, of the twenty-one cows used in these trials, seventeen produced milk giving a significantly higher (odds better than 100 to 1) fat test.

Table 12. Feed consumption, live weights, milk production, and percentages of fat in milk of cows fed dried molasses yeast and oil cake meal in concentrate rations

Ration	Concentrates consumed per cow per day	Green Napier grass consumed per cow per day	Live weights	Milk production per cow per day	Butterfat content of milk	Daily milk production on a 4 per cent fat corrected basis	Superiority in milk production on a 4 per cent fat corrected basis
	Pounds	Pounds	Pounds	Pounds	Per cent	Pounds	Per cent
<i>Control ration</i>							
Trial I.....	18.96	62.2	1059	23.29	3.48	21.47	13.84*
Trial II....	17.01	46.7	1025	25.82	4.11	26.23	12.43*
Trial III..	18.10	42.9	1120	26.30	3.22	23.12	.....
<i>Yeast ration</i>							
Trial I.....	18.59	67.5	1063	20.13	3.58	18.86	.....
Trial II....	17.02	47.5	1018	21.96	4.42	23.33	.....
Trial III..	18.10	42.8	1112	26.20	3.47	24.13	4.37†

* Statistically significant. (Odds greater than 100 to 1.)

† Not statistically significant.

Dried Koa Haole Forage Meal.

Following the outbreak of the war, the uncertainty of shipping and of imports necessitated careful study of local sources of protein supplements. One such source was developed by J. C. Ripperton, Agronomist of the Hawaii Experiment Station, who harvested and dried koa haole forage and ground it in a hammer mill to produce a meal. The supply was limited, however, so that a feeding experiment of necessity consisted of but one double reversal, six-week test with only two cows. The two test rations used (Ration I, Control; Ration J, Koa haole) were made up of the constituents listed in Table 13.

Table 13. Composition of koa haole forage meal and control rations

Feed	Ration I Control	Ration J Koa haole
	<i>Per cent</i>	<i>Per cent</i>
Cane molasses	25.0	26.0
Pineapple bran	43.0	0.0
Soybean oil meal.....	30.0	0.0
Koa haole forage meal.....	0.0	72.0
Salt	1.0	1.0
Steamed bone meal.....	1.0	1.0
Estimated Digestible Crude Protein.....	11.25	6.23
Estimated Total Digestible Nutrients.....	67.00	51.17

The digestible nutrient content of koa haole forage meal was determined by applying known digestive coefficients² for green koa haole to the dried meal. Chemical analysis of the meal made during the trial (Table 14) gave lower protein values than had been expected and hence the ration was deficient in this respect.

Table 14. Analyses of koa haole forage meal and of control and koa haole rations

Feed or ration	Number of analyses	Average percentage on air dry basis as fed					
		Moisture	Protein	Fat	Fiber	N-free extract	Ash
Koa haole forage meal....	3	11.31	12.68	1.86	29.78	39.24	5.13
Ration I (Control).....	3	16.74	13.14	0.97	9.28	53.20	6.67
Ration II (Koa haole ration)....	3	17.06	10.07	1.02	19.84	43.35	8.66

Condensed results of the feeding trial are shown in Table 15. Because of inadequate testing, results can not be considered conclusive. Data suggest, however, that a ration of koa haole forage meal supplemented with cane molasses is not entirely satisfactory for dairy cows if roughage provided consists entirely of low protein content grasses.

² *Hawaii Agricultural Experiment Station Report 1937, (1938), 79.*

Table 15. Feed consumption, live weights, milk production, and percentages of fat in milk of cows fed koa haole forage meal and control rations

Ration	Concentrates consumed per cow per day	Chopped Napier grass consumed per cow per day	Live weights	Milk production per cow per day	Butterfat content of milk	Daily milk production on a 4 per cent fat corrected basis	Superiority in milk production on a 4 per cent fat corrected basis
	Pounds	Pounds	Pounds	Pounds	Per cent	Pounds	Per cent
Control	17.14	51.64	1034	34.64	3.31	31.05	18.92
Koa haole forage meal	24.57	53.71	1030	29.72	3.19	26.11	.....

Table 16 summarizes nutrient requirements based on average production and indicates the nutrients supplied by the rations tested. To have supplied adequate protein in Ration J would have necessitated feeding of greater amounts of the ration than the cows would consume. This condition could have been avoided by the addition of a small quantity of oil cake meal to the ration or by the feeding of leguminous roughage.

Table 16. Nutrients required according to Morrison Standard and supplied by control and koa haole forage meal rations

Requirements and sources	Digestible crude proteins	Total digestible nutrients
	Pounds	Pounds
<i>Required for—</i>		
Maintenance of a 1050 lb. cow.....	0.73	8.95
Production of 28.58 lbs. 4 per cent fat corrected milk	1.40	8.77
	2.13	17.72
<i>Supplied by—</i>		
51.64 lbs. green Napier grass.....	0.28	6.45
17.14 lbs. control ration.....	1.93	11.48
	2.21	17.93
<i>Supplied by—</i>		
53.71 lbs. green Napier grass.....	0.30	6.71
24.57 lbs. koa haole forage meal ration.....	1.53	12.57
	1.83	19.28

Later in this bulletin it will be shown that better results were obtained when green koa haole forage was provided as a grazing or soiling crop in addition to a concentrate ration in which a minimum of oil cake meal compensated for the protein deficiency.

Dried Garbage.

As a result of war conditions, large amounts of Army garbage became available in Hawaii. Removal of excess fat and conversion into a meal for feeding poultry and other classes of livestock which would not ordinarily eat wet garbage was suggested and the work was undertaken by A. S. Ayres under the supervision of J. H. Beaumont, Director of the Hawaii Experiment Station.

To test the suitability of the dried material in rations for dairy cows, a short feeding trial was conducted with the limited material available. Two Holstein cows were fed the garbage ration shown in Table 17 for a two-week period and for comparative purposes records were made of milk production of the two cows during control ration feeding periods of two weeks before and after garbage ration feeding.

Table 17. Composition of garbage and control rations

Feed	Control ration	Garbage ration
	<i>Per cent</i>	<i>Per cent</i>
Cane molasses	25	25
Pineapple bran	43	30
Soybean oil meal.....	30	10
Dried garbage	0	35
Salt	1	(*)
Steamed bone meal	1	(*)
Estimated Digestible Crude Protein.....	11.25	11.10†
Estimated Total Digestible Nutrients.....	67.00	64.35†

* Omitted since garbage supplied ample quantity.

† Nutrients in dried garbage assumed to be 75 per cent digestible.

No chemical analysis was made of the garbage used in this test but the average of seven previous analyses³ showed the following composition on an air dry basis: moisture, 11.46 per cent; protein, 26 per cent; fat, 4.62 per cent; fiber, 1.96 per cent; ash, 11.20 per cent; nitrogen-free matter, 43.78 per cent.

Condensed results showing milk production and feed consumption of the two cows on garbage and control rations are presented in Table 18.

³ A. S. Ayres, *The Preparation of Poultry Feed and Recovery of Fats and Oils from Garbage*, Haw. Agr. Expt. Sta. Prog. Note 39. (October, 1943.)

Table 18. Milk production and concentrate feed consumption of cows fed garbage and control rations

Cow number	Concentrate ration	Daily average	
		Production of milk	Consumption of concentrate
		<i>Pounds</i>	<i>Pounds</i>
162	{Garbage	27.25	15.40
	{Control	28.27	17.50
206	{Garbage	23.35	14.30
	{Control	22.30	14.25
Both cows	{Garbage	25.30	14.85
	{Control	25.28	15.87

At the start of the experiment, the cows refused some of the garbage ration, but at the end of one week were consuming their normal quantity. Napier grass to the limit of appetite was furnished as roughage throughout the experiment. Milk production was practically the same on both feeds in this short trial and no unfavorable taste was detected in the milk at any time during the test.

LEGUMINOUS ROUGHAGES AS SUBSTITUTES FOR PROTEIN CONCENTRATES

Hawaii does not at present produce commercial quantities of high protein supplements of plant origin, but several legumes are grown which, if used as roughages, would materially reduce the quantity of protein supplements now added to concentrate rations of dairy cows. Experimental work has shown the value of two common legumes—pigeon pea (*Cajanus cajan*), and koa haole (*Leucaena glauca*). A third legume of promise, *Desmanthus virgatus*, was used in a feeding experiment reported earlier.⁴

Koa Haole Soiling and Pasture Crops.

Effectiveness of koa haole as a partial substitute for imported protein supplements was determined in a series of eleven experiments. Three were of the double reversal type, and eight were observation experiments. Koa haole was either grazed or used as a soiling crop for periods ranging from two to four weeks. During the periods when koa haole was made available, a supplementary ration with reduced protein content was fed.

In the three double reversal experiments, detailed fat-test and live-weight determinations were made. In the eight observation tests, milk production during periods when the cows were fed non-leguminous roughages (largely

⁴L. A. Henke, *Roughages for Dairy Cattle in Hawaii*, Haw. Agr. Expt. Sta. Bul. 92 (1943), 16.

Napier grass) and high protein supplements was compared with yields during test periods on koa haole and reduced protein rations.

Composition of the concentrate rations used in these trials, as well as in those reported later with pigeon pea forage, is shown in Table 19.

Table 19. Composition of concentrate rations fed in various trials with koa haole and pigeon pea forage

Feed	Ration F	Ration H	Ration I	Ration K	Ration L
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Cane molasses	25.0	33.3	25.0	25.0	33.3
Pineapple bran	38.0	50.7	43.0	30.0	30.0
Coconut oil meal	10.0	0.0	0.0	0.0	0.0
Soybean oil meal	25.0	13.3	30.0	30.0	12.0
Salt	1.0	1.4	1.0	1.0	1.4
Steamed bone meal	1.0	1.3	1.0	1.0	1.3
Corn meal	0.0	0.0	0.0	13.0	22.0
Estimated Digestible Crude Protein*	11.30	5.42	11.25	12.09	6.40
Estimated Total Digestible Nutrients*	67.83	63.57	67.00	69.08	66.90

* Based on previous analyses of feeds used. It is assumed that the various constituents in the different mixtures were of average composition.

Rations F, I, and K, which contain similar amounts of digestible nutrients, were fed with non-leguminous roughages while the low protein rations H and L were fed in addition to leguminous roughages. Minor variations and substitutions were necessary in the rations because at times certain feeds were not obtainable.

Chemical analyses of Ration F and of feeds and roughages used in experiments with koa haole and pigeon pea are summarized in Table 20.

Table 20. Percentage composition of roughages, cane molasses, pineapple bran, and of ration F*

	Experi- ment number	Number of samples	Moisture	Crude protein	Fat	Crude fiber	N-free matter	Ash
Koa haole	I	54	67.40	6.14	0.68	12.89	10.62	2.27
Koa haole	II	54	68.06	6.38	0.73	11.83	11.07	1.93
Koa haole	III	54	66.92	5.88	0.81	12.11	11.99	2.29
Koa haole	X	17	67.30	4.21	0.43	14.21	11.36	2.49
Pigeon pea	I	12	56.20	5.44	1.81	17.67	16.78	2.01
Pigeon pea	II	6	62.30	4.83	1.33	15.46	14.29	1.79
Napier grass	I	54	80.70	1.34	0.31	7.37	7.63	2.65
Napier grass	II	54	74.52	0.95	0.37	10.64	10.91	2.61
Napier grass	III	54	77.80	0.90	0.35	9.63	8.71	2.61
Cane molasses	III	6	23.52	3.19	0.35	0.03	63.04	9.87
Pineapple bran	III	6	12.93	3.77	0.95	16.09	63.03	3.23
Ration F	III	6	17.25	14.51	2.23	8.01	50.89	7.11

* On green or air dry basis as fed.

Table 21 condenses feed consumption and milk production data from the first three experiments in the green koa haole feeding trials. Six cows were used in each of the first two trials and eight cows in the third. The experiments were of the double reversal type and were continued for twelve weeks.

Table 21. Feed consumption, live weights, milk production, and percentages of fat in milk of cows fed koa haole and control rations

Roughage experiment	Concentrates consumed per cow per day			Chopped green roughage consumed per cow per day	Live weights	Milk production per cow per day	Butterfat content of milk	Daily milk production on a 4% F.C.* milk basis	Superiority in milk production on a 4% F.C.* milk basis
	Ration F	Cane molasses	Pine-apple bran						
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Per cent	Pounds	Per cent
<i>Green koa haole</i>									
I	18.34	.....	.....	48.33	1169	27.67	3.40	25.17	9.06†
II .....	.....	5.00	9.00	56.89	1169	26.28	3.54	24.46	1.96†
III .....	.....	4.82	6.61	52.79	948	20.23	3.95	20.22	.....
<i>Average II and III</i>	.....	4.91	7.80	54.84	1058	23.25	3.74	22.34	.....
<i>Napier grass</i>									
I	17.38	.....	.....	57.00	1183	25.82	3.29	23.08	.....
II	16.78	.....	.....	56.43	1164	25.47	3.61	23.99	.....
III	15.45	.....	.....	52.34	982	23.04	3.86	22.39	10.73‡
<i>Average II and III</i>	16.11	.....	.....	54.38	1073	24.25	3.73	23.19	3.80†

* Fat corrected.

† Not statistically significant.

‡ Odds greater than 100 to 1 that this superiority did not occur by chance.

Tabulated results from experiments comparing use of koa haole as soiling and grazing crops are given in Table 22.

Non-leguminous roughages with high protein concentrates were always fed to the cows in the experiments before and after the trial periods on rations including koa haole. For example, data in Experiment IV (Table 22) are based on average production two weeks before and two weeks after the four-week koa haole feeding period.

In Experiments IX and XI, some Napier grass was supplied in night paddocks. Cows seemed to want some roughage at night and it was impossible to let them graze in the koa haole area after dark.

Table 22. Milk production of cows fed koa haole with reduced protein content in concentrate ration compared with production before and after koa haole feeding

Experiment number	Number of cows	Roughage fed	Soiling crop or grazed	Concentrate ration	Number of weeks on ration*	Average daily consumption		Average daily milk yield	Superiority in milk production
						Roughage†	Concentrates		
						Pounds	Pounds	Pounds	Per cent
IV	17	Napier	Soiling	F	4	50.5	15.7	17.2	3.0
		Koa haole	Grazed	H	4	.....	15.6	16.7	....
V	18	Napier	Soiling	I	4	58.7	16.0	22.7	....
		Koa haole	Grazed	H	4	.....	16.5	23.3	2.7
VI	23	Napier	Soiling	I	4	62.5	16.6	23.3	3.1
		Koa haole	Grazed	H	2	.....	17.0	22.6	....
VII	24	Napier	Soiling	K‡	4	68.0	15.5	19.9	11.2
		Koa haole	Grazed	L	2	.....	15.6	17.9	....
VIII	16	Napier	Soiling	K‡	4	79.0	16.0	20.3	....
		Koa haole	Grazed	H	4	.....	16.1	20.4	0.5
IX	12	Napier	Soiling	K	4	80.2	16.6	22.3	2.7
		Koa haole	Grazed	H	3	(§)	16.6	21.7	....
X	9	Napier	Soiling	I	4	83.3	15.8	23.9	3.5
		Koa haole	Soiling	H	3	59.5	16.0	23.1	....
XI	13	Napier	Soiling	I	4	84.9	15.6	25.0	....
		Koa haole	Grazed	H	3	(§)	15.6	26.5	6.0
Av. of eight experiments	16.5	Napier	Soiling	F,I,K	4.0	70.9	16.0	21.8	1.4
		Koa haole	Grazed	H,L	3.12	.....	16.1	21.5	....

* Non-leguminous roughages with high protein content concentrates always fed before and after koa haole feeding.

† Shows quantity Napier supplied. Weigh backs, if any, not determined.

‡ A few cows fed other rations part of period.

§ Some Napier grass (35.2 lbs. in IX; 25.1 lbs. in XI) supplied in night paddock.

The use of koa haole soiling or pasture crops in this series of experiments suggests the possibility of materially reducing the soybean oil meal content of rations when this leguminous plant is used as roughage. The actual saving of soybean oil meal on a per cow per day basis ranged from 2.6 to 4.2 pounds with an average of 3.0 pounds saved per cow per day (Table 23). In a 100 cow dairy, this saving would amount to 300 pounds per day or 4.5 tons per month.

Table 23. Saving in soybean oil meal by feeding koa haole instead of Napier grass or other non-leguminous roughage

Experiment number	Saving in soybean oil meal Pounds
I.....	0.0*
II.....	4.2
III.....	3.9
IV.....	3.5
V.....	2.6
VI.....	2.7
VII.....	2.8
VIII.....	2.7
IX.....	2.8
X.....	2.6
XI.....	2.6
Average.....	3.0

* Same concentrate ration fed with each roughage.

It must be remembered, however, that though koa haole is widespread in various waste areas, harvesting would be difficult and expensive with a limited labor supply and yields would be only about one third those of Napier grass. Whether substitution of koa haole for Napier grass would be practical would depend on land values and on availability of labor.

Pigeon Pea Forage.

Two experiments using pigeon pea forage as a soiling crop followed the same procedure used in the trials with koa haole. Analyses of the pigeon pea forage used in the experiments are included in Table 20. Condensed data in Table 24 show results similar to those obtained in the koa haole studies.

Table 24. Milk production of cows fed pigeon pea forage and reduced protein content concentrate rations compared with production before and after pigeon pea feeding

Experiment number and soiling crop roughage	Number of cows used	Concentrate ration	Feeding period Weeks	Average daily consumption		Average daily milk production Pounds	Superiority in milk production Per cent
				Roughage* Pounds	Concentrates Pounds		
I							
Napier grass....	10	K and I	4	98.7	16.1	22.9	0.8
Pigeon pea.....	10	H	2	46.2	16.1	22.7	....
II							
Napier grass....	16	I	2	61.5	15.5	26.0	....
Pigeon pea.....	16	H	1	44.1	15.6	26.1	0.4

* Shows roughage supplied. Weigh backs, if any, not determined.

With pigeon pea forage feeding, a saving of 2.7 pounds of soybean oil meal per cow per day was effected in the first experiment and 2.6 pounds in the second. No significant reduction in milk flow was noted. It should be pointed out that pigeon pea, like koa haole, gives much lower yields of forage than Napier grass. In addition, pigeon pea plants, unlike Napier grass, do not maintain themselves when cut fairly short with a corn binder.

SUMMARY AND CONCLUSIONS

The experiments presented in this bulletin were designed to gather data on the use, effect, and value of locally produced feeds as substitutes for imported protein concentrates used in dairy cow rations. The possibilities and limitations of local products have been demonstrated. Whether substitution of local products would be practical in normal times would depend on land values and on cost, regularity, and adequacy of labor and of imports of protein concentrates. Thus, after the war, it may be indicated that in spite of proved worth of Hawaii-produced feeds as protein substitutes, it would be most economical for the dairyman to grow Napier grass for use as roughage and purchase imported, high protein supplements just as he did before the war.

The summary which follows lists conclusions drawn from observations and experimental data.

1. High protein content supplements are essential in Hawaii since local by-product feeds—cane molasses and pineapple bran—are both low in protein.

2. Heavy feeding of concentrates is practiced in Hawaii. This is necessary since rations containing large amounts of pineapple bran and cane molasses are lower in total nutrients than if the rations were composed largely of cereal grains and their by-products.

3. The protein content of the concentrate ration should be adjusted to the quantity of concentrates fed. When large quantities are fed, the protein content should be lower.

4. With heavy feeding, 12 per cent digestible crude protein in the concentrate ration generally meets protein needs.

5. Sesame oil meal is equal to soybean oil meal as a protein supplement in dairy rations.

6. Soybean oil meal resulted in slightly higher milk production than cottonseed oil meal, but the differences were not statistically significant.

7. In two out of three trials soybean oil meal proved slightly superior to dried yeast as a protein supplement in dairy rations.

8. Results from preliminary experiments with dried koa haole forage meal indicate that protein requirements are not met by this feed.

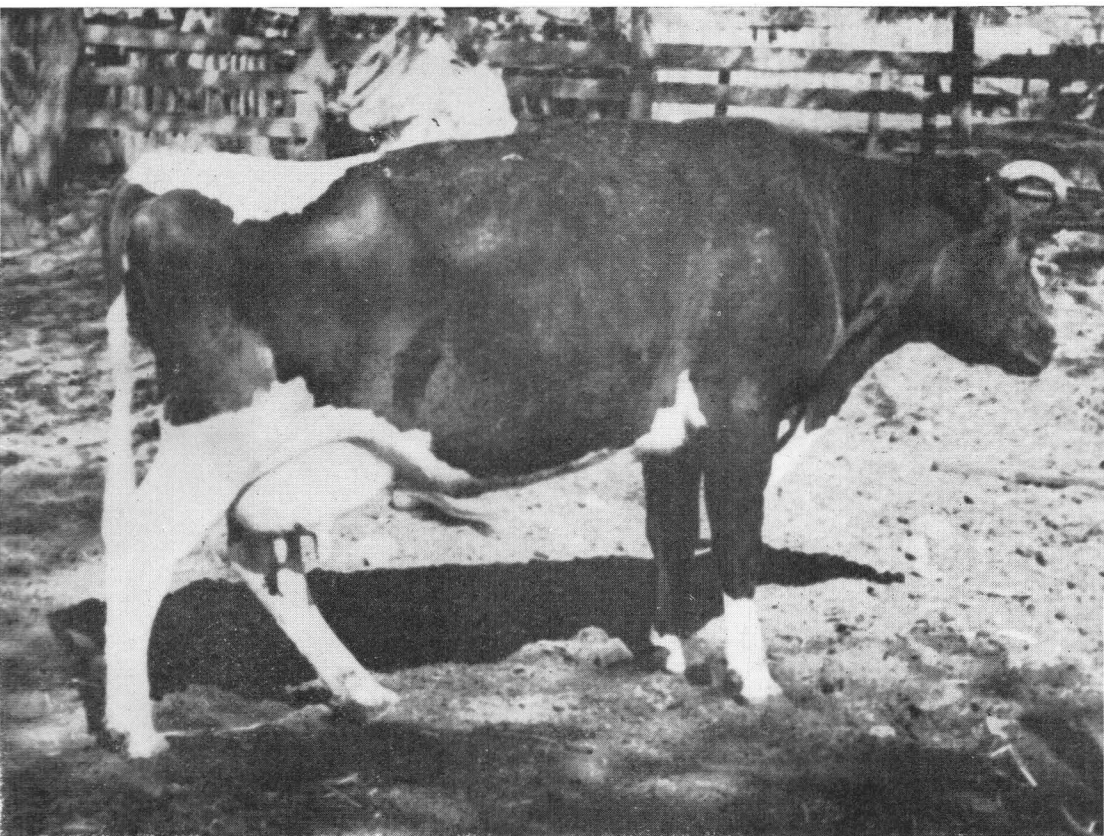
9. No reduction in milk yield resulted when cows were fed dried garbage rations. No unfavorable taste was detected in the milk.

10. A saving of about three pounds of soybean oil meal per cow per day resulted when either koa haole or pigeon pea forage was substituted for Napier grass. The high protein content of these legumes permitted a material reduction in the soybean oil meal content of the concentrate. Milk production was not adversely affected.

ACKNOWLEDGMENTS

The author is indebted to his former associate S. H. Work for helpful suggestions; to Charles Maruyama, former farm superintendent and now Junior Animal Husbandman, for much assistance in carrying out the details of these experiments; to J. C. Ripperton, Agronomist, for directing the chemical analyses of roughages and feed mixtures; and to N. K. Pekelo, Peter Yap, G. W. H. Goo, Manuel Ventura, and K. Kuwamoto—foremen and superintendents of the University of Hawaii Farm during the period of these trials—for their assistance in the investigations.

The helpful suggestions of E. L. Willett, Associate Animal Husbandman; Paul Gantt, Specialist in Animal Husbandry; and C. I. Draper, Associate Poultry Husbandman, who read this manuscript, are also gratefully acknowledged.



Uniwai Sarcastic Prilly, a 15½-year-old cow, used
in nine of the trials described in this bulletin



Harvesting koa haole with a corn binder

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